SETI, The Drake Equation [a.k.a. the Green Bank Equation], and the Overestimation of the Probability of Life in the Rest of the Universe

Scott Matheson Hitchcock

Version as of 01/29/2020

Abstract: SETI [Search for Extraterrestrial Intelligence] is driven by the belief that there is life, possibly intelligent, in the universe beyond earth. In order to estimate the number of possible places [planets] in the universe where life could exist and presumably evolve into intelligent civilizations that we might be able to detect or even communicate with, an early attempt to discuss this estimation process was described by the **Drake Equation** [***a.k.a. the*** **Green Bank Equation**]. This has been used to justify allocation of resources and funding for SETI projects. This equation is at first glance seemingly obvious but there are many simple underlying assumptions that make it difficult to use and in fact in it simplicity it overlooks the complex set of conditions necessary for life to arise and evolve into a state that is detectable from our position. Research into the **origins of life [1,2,3]** illuminate the parameters that impact SETI strategies. There are many overlooked **factors**, conditions, and requirements that must be met for life to exist and evolve on other planets in the famous Drake Equation which outlines a strategy for estimating the probability of life elsewhere in the universe. Many of these requirements have subtle contributions but are essential for life as we know it here on Earth. These probabilities are difficult to estimate for use in the following equation. Modification of the Drake Equation with this set of additional factors naturally reduces N = the number of civilizations to a negligible number possibly zero for life outside of this island Earth. The misuse of the Drake Equation for self-interests such as promoting space exploration and colonization in light of project funding and pseudoscience promotion are discussed. Note that the original terms of the equation may imply some of the items listed as other factors but this still needs to be clarified due to overly simplistic estimate possibly hidden in the terms but not clearly or correctly identified and limiting factors that would drastically reduce the value of N. ***It may be that with so many highly specific and necessary conditions that are needed to be met for life that the extremely large number of planets in the universe can't outweigh the extremely small probability of life predicted when accounting for the stack up of the probabilities encompassing all the factors involved in all the bio-chemical processes and environmental parameters thus leading to the uniqueness of life here on Earth.*** **The purpose of this exercise is to try to illustrate some of these overlooked factors for modification of the Drake Equation to reflect the reality of the complexity of life and its requirements.**

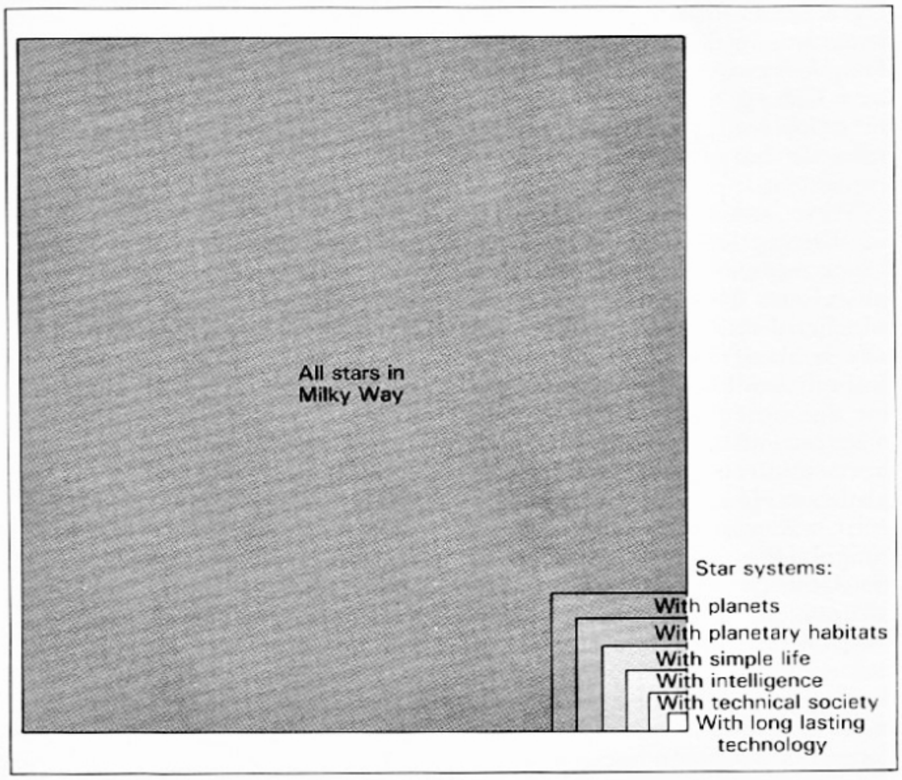


FIGURE 29.10 Of all the star systems in our Milky Way (represented by the largest box), progressively fewer and fewer have each of the qualities typical of a long-lasting technological society (represented by the smallest box at the lower right corner).

The Drake Equation:

$N = R_* * f_p * n_e * f_l * f_i * f_c * L *$ [all other factors]

Where ***N*** **= the number of civilizations in our galaxy [or more generally the universe] with which communication might be possible**

and the original factors are:

R_* **= the average rate of star formation in our galaxy [scale up for the universe]**
f_p **= the fraction of those stars that have planets**
n_e **= the average number of planets that can potentially support life per star that has planets**
f_l **= the fraction of planets that could support life that actually develop life at some point**
f_i **= the fraction of planets with life that actually go on to develop intelligent life (civilizations)**
f_c **= the fraction of civilizations that develop a technology that releases detectable signs of their existence into space**
L **= the length of time for which such civilizations release detectable signals into space**

[all other factors] **Here is where the problem of overestimation of N occurs.**

INTERLUDE 29-1 ***More Terms in the Equation?***

Some researchers feel that the Green Bank equation used in this chapter is an inadequate guide to the number of galactic civilizations. They suggest that many additional terms are needed to fully describe the evolution of a technological civilization from inanimate matter. For example, we could imagine additional terms with labels like "fraction of those planets bearing plant life that also develop animal life" or "fraction of those hunter-gathering people who eventually evolve language" or even "fraction of those intelligent civilizations that invent religion to help stabilize their societies." Numerous other terms could be invented—a new term for every conceivable evolutionary development. Accordingly, our equation would balloon into one having perhaps hundreds, even thousands of terms.

This argument is often used by researchers, usually biologists and chemists, to suggest that the prospects for extraterrestrial life are extremely small. An equation having hundreds of terms, with each term equal to less than 1, inevitably yields a very small result. For example, even if every one of 100 terms has a 9-out-of-10 chance, all 100 terms multiplied together yield a value of $(0.9)^{100}$, or approximately 0.00003. This somewhat pessimistic view suggests that because so many steps are required for the evolution of a technological society, the chance of *all* these steps randomly occurring anywhere else is so small as to make extraterrestrial life virtually impossible.

Optimists argue, on the other hand, that evolution is not entirely random. They furthermore argue that there are likely to be many, many paths from simple organisms to technological life. In other words, the exact sequence of steps in life's advancement on Earth may well be unlikely ever to occur more than once, but many alternative evolutionary paths permit the rise of more-or-less equivalent life forms. This optimistic argument suggests that technological civilizations are inevitable, given the proper conditions and enough time.

The optimistic researchers, usually astronomers and physicists, also argue that additional terms in the equation are not really needed. Adding more terms is the same as dividing each of the terms already used in this chapter into smaller steps describing the overall road to technological intelligence. Yet many of these additional factors leading to, for example, the onset of life or intelligence would seem to be theoretical certainties. Expressed another way, many if not most of the subterms representing any additional factors would have numerical values very close or even equal to 1.

Consider a specific example. In the Green Bank equation, we used a term labeled "fraction of life-bearing planets on which intelligence develops." This term could be subdivided to include many factors, including fractions that estimate the chances for the development of a primitive nervous system, eyes, learning ability, sociability, communications, dexterity, tools, fire, cities, science, and so on. But many researchers, who have studied each of these additional factors of intellectual development, maintain that almost all of them are virtually sure bets, assuming enough time for life to so develop. In fact, many of these factors are interconnected, the development of one almost surely leading to the development of others. Hence subterms representing each of these additional factors are practically equal to 1. The same can be said about the subdivision of other terms in our Green Bank equation. Regardless of the number of terms in the equation, if most of them are theoretical certainties, their product need not become very small.

The upshot is that an analysis of the Green Bank equation presented elsewhere in this chapter is probably independent of the number of terms used. Regardless of how we cast the equation, it amounts to a shorthand version of an extremely complex problem. Making the equation more complex by adding more terms does not really alter the final result.

The Green Bank equation is valuable in that it provides a framework for a discussion of the prospects for life elsewhere in the Universe. If, while trying to evaluate it numerically, we come across some rigorous argument to exclude extraterrestrial intelligence, we'll then be able to conclude that a search for galactic aliens is not a useful allocation of our time, effort, money, and resources. If, on the other hand, we cannot find any definitive arguments to exclude extraterrestrial life, our civilization will almost surely try to discover it sooner or later. Human nature seemingly compels us to make a complete inventory of the Universe, and that includes all radiation, all matter, and all life.

This is a good description of the problem [above] [2]

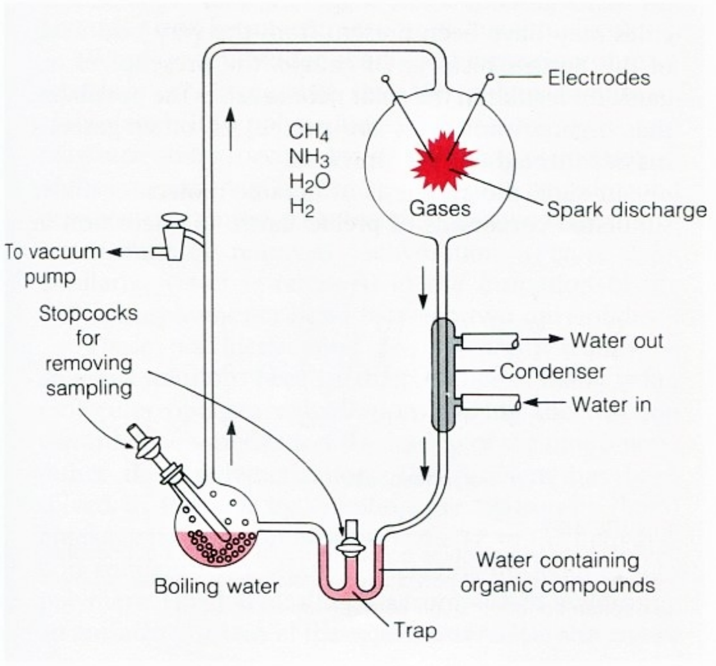
Following is a preliminary list of factors [a probability estimate or metric not assigned] that are not taken into account in the original terms listed by Drake. The oversimplification of the understanding of our very complex life system and it requirements leads to the predication of artificially large numbers for N>>1 [N=1 for earth alone].

Note that additional terms in this equation will reduce the total number N of possible civilizations! Also note that the items listed below should be looked at as: "the fraction of planets that have ______[item #]______ ..."

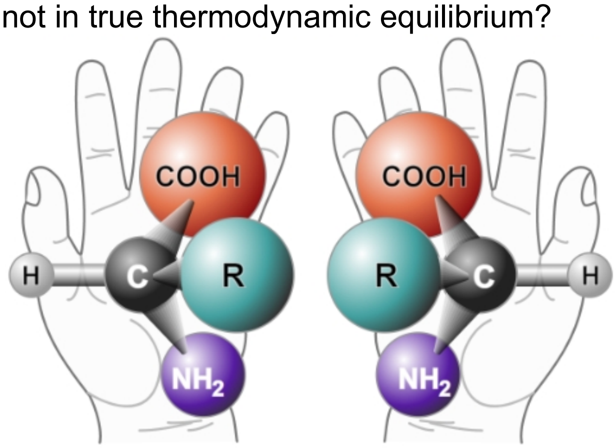
Below is an attempt to list additional or hidden factors needed to consider when determining if life can originate, sustain, and evolve [*no particular order by weight, strength or probability, i.e. no value, metric, or scale assigned to each*]:

1. **Solar Activity**, flares, coronal mass ejections [CMEs], sunspots, solar magnetic fields, solar winds?
2. Does the planet have a **moon**?
3. **Tides** necessary for creating micro-climates and Eco-niches? Tidal influences on biological systems?
4. **Moon protection** of the planet from **asteroid collisions**?
5. **Tilt of the planets axis** necessary for a weather machine?
6. A **Weather Machine** that creates the subtle energy dynamics to introduce a balance between chaos and order? **Winds**?
7. A **magnetic field** to deflect stellar and cosmic radiation?
8. **Oceans** that respond to the weather machine in order to create proto-cells? **Ocean currents**?
9. **Lipids** in aqueous solution that can form proto-cell semi-permeable wall membranes separating the interior space of the cell from the environment thus allowing a decrease in the entropy inside the cell allowing for organization of biochemicals while isolating the interior from the increased entropy of the environment around it?
10. Availability of **organic molecules**?
11. Not too much **oxygen** or too little? Excess oxygen, oxidation, and burning that destroy carbon based molecules and life?
12. Enough [UV] **radiation** to stimulate mutations but not so much as to destroy life?
13. **Toxic** gases in the environment?
14. Pure **water** vs. Sea water? Clearly the **chemical** and **physical** properties of **water** beyond its mere presence needs to be considered.
15. **Shorelines,** waves, beach materials? Waves too strong or weak?
16. **Precipitation**? Rain? Snow? Ice?
17. **Polar caps**?
18. **Greenhouse effects**? Clouds? Clear Skies?
19. **Volcanic activity**?
20. **Continents**? Islands? Tectonic plates?
21. **Ozone** layer protection?
22. **Depth of oceans**? **Thermal reservoirs**? Deep ecosystems? Extremophiles ?
23. **Sedimentation** and other geological processes that shape land water interfaces?
24. **Surface tension** of **water**---dissolved, colloidal, and suspended organic and inorganic substances in the water could create conditions negating those parameters necessary for the creation and emergence of life.
25. **Bubble formation in the waters [surface or underground] of oceans, lakes or rivers** may be necessary for the creation of prototype cell structures and required in order to bring atmospheric oxygen/gases into the water to support waterborne living

systems. If the **surface tension** is too high or low compared to that of Earth this could negate the emergence and continuing existence of life at the cellular level.



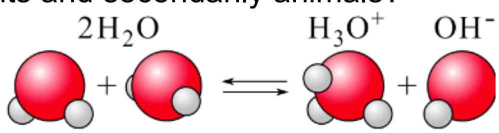
26. **Lightning**? Stanley Miller's experiment [above- creation of amino acids etc. From precursor gases and molecules?
27. **Atmospheric gases for creation of organic compounds**? Methane, CO_2 , nitrogen, etc.?
28. **Mountains** and **elevated land above sea level**? Needed for animals to survive long enough to evolve into **land creatures** that can create instruments and tools leading to possible communications systems that would not occur for animals restricted to living in rivers, lakes or oceans only
29. **Molten metallic core of planet**? [see item 6 above] Magnetism global or local?
30. **Decay radiation** from planetary sources – minerals etc.?
31. **Atmospheric chaos** that limits molecular growth? **Entropy vs. order** in balance yet not in true thermodynamic equilibrium?



32. **Handedness of molecules** [above]. [chirality or chiral: a molecule or ion is called chiral if it cannot be superposed on its mirror image by any combination of rotations

and translations. A chiral molecule is asymmetric in such a way that the structure and its mirror image are not superimposable. Chiral compounds are typically optically active; large organic molecules often have one or more chiral centers where four different groups are attached to a carbon atom.]? Molecules on earth tend to favor Most substances relevant to biology are chiral, such as carbohydrates (sugars, starch, and cellulose), the amino acids that are the building blocks of proteins, and the nucleic acids. In living organisms, one typically finds only one of the two enantiomers [an enantiomer is one of two stereoisomers that are mirror images of each other that are able to be be superimposed, much as one's left and right hands are mirror images of each other that cannot appear identical simply by reorientation of a chiral compound.] For that reason, organisms that consume a chiral compound usually can metabolize only one of its enantiomers. For the same reason, the two enantiomers of a chiral pharmaceutical usually have vastly different potencies or effects. NOTE: the selection of one or the other handedness of molecules may be influenced by **polarization of light in the atmosphere.**

33. **Polarization of starlight** by the atmosphere? Preferred asymmetric molecules for biological systems?
34. **Photosynthesis**? Chlorophyll? Production of O_2, CO_2 complex molecules needed to provide energy for plants and secondarily animals?



35. **Water properties** such as **Self-ionization** [above]? The self-ionization of water (also autoionization of water, and autodissociation of water) is an ionization reaction in pure water or in an aqueous solution, in which a water molecule, H_2O, deprotonates (loses the nucleus of one of its hydrogen atoms) to become a hydroxide ion, OH^- [strong base]. The hydrogen nucleus, H^+ [strong acid], immediately protonates another water molecule to form hydronium, H_3O^+. It is an example of autoprotolysis, and exemplifies the amphoteric nature of water. This process leads to short lived strong acid and bases and is a natural process especially in pure water. This accounts for corrosion in ultra pure water systems where the lifetimes of these ions can be modified by flow, proximity to surfaces that can be corroded, temperature, and random motion chaos of nearby water molecules. **This process can limit molecular growth of biomolecules**.

TYPES OF CARBON COMPOUNDS AT DIFFERENT STELLAR TEMPERATURES

Type of Star	Absolute Temperature	Carbon Combinations
O	25,000°	C^{++}; C^{+}; C
B	20,000—15,000°	C
A	12,000°	C; CH (traces)
G	8,000°	C_2; CH; CN
M	4,000°	C_2; CN; CH (very intense bands)
N	2,000°	$C^{12}—C^{12}$; $C^{12}—C^{13}$; $C^{12}—C^{14}$; CN; CH

36. **Carbon Molecules** [above]? What carbon molecules are available as a function of star temperatures? Do the carbon-based building blocks exist for the creation of simple and complex carbon molecules and biomolecules? The illustration is from Oparin's book listed below [1].
37. Does the environment support **complex metabolic pathways** without destroying them through chaotic turbulence or wild energy variations such as temperature, diffusion, convection, other thermal currents etc.? **Support of respiration and cellular energy production by feeding?** [3]
38. **Food source distribution** and spatial density close enough together to support life but not so separated that potential animals might starve?
39. **Earthquakes** and unstable land masses that can destroy or modify eco-niches?
40. ???...

NOTE: The reader is encouraged to add additional factors to this list and edit out duplications and redundancies. This exercise is meant mainly to illustrate the idea that looking life in the universe by using the Drake Equation needs to be done with an open mind. This author does not take a position about whether life exists beyond Earth only that it has far more complexity of things that must stack up constructively than was assumed in the Drake Equations original form.

Bibliography

1. "Origin of Life" by A. I. Oparin, Dover Publications 1953
2. "UNIVERSE An Evolutionary Approach to Astronomy" by Eric Chaisson, Prentice Hall 1988
3. "CELLS' by David M. Prescott, Jones and Bartlett Publishers 1988

The **habitable zone** is the range of distances from a star where liquid water might pool on the surface of an orbiting planet. If a planet is too close to its parent star, it will be too hot and water would have evaporated. If a planet is too far from a star it is too cold and water is frozen. Stars come in a wide variety of sizes, masses and temperatures. Stars that are smaller, cooler and lower mass than the Sun (M-dwarfs) have their habitable zone much closer to the star than the Sun (G-dwarf). Stars that are larger, hotter and more massive than the Sun (A-dwarfs) have their habitable zone much farther out from the star.